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TI **Steel** having good cutability and cold forgeability for machinery parts
IN Hoshino, Toshuki; Iwamoto, Takashi; Matsuzaki, Akihiro; Amano, Kenichi
PA Kawasaki Steel Co, Japan
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AB The title **steel** contains. **C** 0.1-1.5, Si <0.5, **Mn** 0.1-2.0, Al 0.01-0.5, B 0.0003-0.0150, N 0.0015-0.0150, O .ltoreq.0.0030, Ni 0.1-3.0,Cu 0.1-3.0, and Co 0.1-3.0%. The **steel** mainly consists of ferrite and graphite.

0.1-1.5 C
≤0.5 Si
0.1-2.0 Mn
P
S
0.1-3 Cu
0.1-3.0 Ni
Cr

Fe

PATENT ABSTRACTS OF JAPAN

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(54) STEEL FOR MACHINE STRUCTURE EXCELLENT IN MACHINABILITY AND COLD FORGEABILITY

(57)Abstract:

PURPOSE: To impart a steel for machine structures jointly with machinability and cold forgeability.

CONSTITUTION: This steel has a compsn. contg., by mass, 0.1 to 1.5% C, <0.5% Si, 0.1 to 2.0% Mn, 0.01 to 0.5% Al, 0.0003 to 0.0150% B, 0.0015 to 0.0150% N and ≤0.0030% O, moreover contg. one or ≥ two kinds selected from 0.1 to 3.0% Ni, 0.1 to 3.0% Cu and 0.1 to 3.0% Co, furthermore contg. one or ≥two kinds selected from 0.005 to 0.15% P, 0.005 to 0.25% S, 0.003 to 0.10% Se, 0.0002 to 0.30% Ca, 0.002 to 0.5% Te, 0.03 to 0.30% Pb and 0.01 to 0.3% Bi as machinability improving elements, and the balance substantial Fe and has a metallic structure mainly consisting of ferrite and graphite.

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CLAIMS

[Claim(s)]
[Claim 1] C:0.1 - 1.5 mass% Less than [Si:0.5 mass%], Mn: 0.1 - 2.0 mass% aluminum:0.01 - 0.5 mass%, B:0.0003 - 0.0150mass%, and N:0.0015 - 0.0150mass %, Less than [O:0.0030mass%] is included. And nickel:0.1 - 3.0 mass%, One sort chosen from from while of Co:0.1 - 3.0 mass%, or two sorts or more are contained Cu:0.1 - 3.0 mass%. The remainder is the steel for machine structural use excellent in the machinability and formability in cold forging to which it becomes composition of Fe substantially and a metal texture is moreover characterized by the bird clapper more mainly than a ferrite and a graphite.
[Claim 2] C:0.1 - 1.5 mass% Less than [Si:0.5 mass%], Mn: 0.1 - 2.0 mass% aluminum:0.01 - 0.5 mass%, B:0.0003 - 0.0150mass%, and N:0.0015 - 0.0150mass %, Less than [O:0.0030mass%] is included. And nickel:0.1 - 3.0 mass%, One sort chosen from from while of Cu:0.1 -3.0 mass%Co:0.1 - 3.0 mass%, or two sorts or more are contained. Furthermore, it is Cr:0.05 - 1.0 mass%. One sort chosen from from while of Mo:0.05 - 0.5 mass%, or two sorts are contained. The remainder is the steel for machine structural use excellent in the machinability and formability in cold forging to which it becomes composition of Fe substantially and a metal texture is moreover characterized by the bird clapper more mainly than a ferrite and a graphite.
[Claim 3] C:0.1 - 1.5 mass% Less than [Si:0.5 mass%], Mn: 0.1 - 2.0 mass% aluminum:0.01 - 0.5 mass%, B:0.0003 - 0.0150mass%, and N:0.0015 - 0.0150mass %, Less than [O:0.0030mass%] is included. And nickel:0.1 - 3.0 mass%, One sort chosen from from while of Cu:0.1 -3.0 mass%Co:0.1 - 3.0 mass%, or two sorts or more are contained. Further V:0.05 - 0.5 mass% At least one sort chosen from from while of Nb:0.005-0.05mass%Ti:0.005 - 0.05mass% is contained. The remainder is the steel for machine structural use excellent in the machinability and formability in cold forging to which it becomes composition of Fe substantially and a metal texture is moreover characterized by the bird clapper more mainly than a ferrite and a graphite.
[Claim 4] C:0.1 - 1.5 mass% Less than [Si:0.5 mass%], Mn: 0.1 - 2.0 mass% aluminum:0.01 - 0.5 mass%, B:0.0003 - 0.0150mass%, and N:0.0015 - 0.0150mass %, Less than [O:0.0030mass%] is included. And nickel:0.1 - 3.0 mass%, One sort chosen from from while of Cu:0.1 -3.0 mass%Co:0.1 - 3.0 mass%, or two sorts or more are contained. Furthermore, it is Cr:0.05 - 1.0 mass%. One sort or two sorts which were chosen from from while of Mo:0.05 - 0.5 mass%, V:0.05 - 0.5 mass% At least one sort chosen from from while of Nb:0.005 -0.05mass% Ti:0.005 - 0.05mass% is contained. The remainder is the steel for machine structural use excellent in the machinability and formability in cold forging to which it becomes composition of Fe substantially and a metal texture is moreover characterized by the bird clapper more mainly than a ferrite and a graphite.
[Claim 5] As opposed to the steel indicated to any one steel of the claims 1-4 further P:0.005 - 0.15mass%, S:0.005 - 0.25mass% and Se:0.003 - 0.10mass%, calcium: 0.0002 - 0.30mass% and Te:0.002 - 0.5 mass%, Pb: The steel for machine structural use excellent in the machinability and formability in cold forging which make it come to contain one sort or two sorts or more of improvement elements in machinability chosen from from while of 0.03 - 0.30mass% and Bi:0.01 - 0.3 mass%.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] this invention means improvement in the machinability and formability in cold forging especially about the carbon steel for machine structures used as a material of machine parts, such as an industrial machine and an automobile.
[0002]
[Description of the Prior Art] After machine parts, such as an industrial machine and an automobile, are made from the carbon steel for machine structures, or alloy steel and are generally fabricated by the predetermined configuration through cold forging or a cutting process, in order to secure the intensity as a machine part, hardening and tempering processing are performed and let them be products. Therefore, from this kind of steel materials, formability in cold forging is required simultaneously with machinability.
[0003] The method of adding free-cutting elements, such as Pb, S, Bi, Te, and calcium, to steel materials, and making a nonmetallic inclusion form into steel as a method of improving the machinability of steel materials is well-known. On the other hand, reducing the nonmetallic inclusion in steel contrary to the case of machinability as a means to improve the deformability at the time of formability in cold forging, especially cold forging is performed. Therefore, machinability and formability in cold forging were very difficult for reconciling these, though it is the property always demanded from steel-for-machine-structural-use material, such as an industrial machine and autoparts, and there was a problem that a sacrifice fake colander was not obtained, about one of properties.
[0004] As a solution of the above-mentioned problem, the steel materials which raised formability in cold forging and machinability simultaneously are proposed by graphitizing the cementite in steel by JP,51-57621,A. However, according to examination of this invention persons, it has left the problem described below. That is, Si content by the above-mentioned method Since it is high, although graphitization completes the cementite in steel early comparatively with 1.9 - 3.0 mass%, in order that Si may dissolve in a ferrite phase and may reduce the deformability of a ferrite, the deformability at the time of cold forging falls, and its deformation resistance at the time of cold forging is also high by the dissolution potentiation of Si. Moreover, by this method, the graphite particle size after graphitization accumulated greatly, and the improvement of the deformability in cold forging and machinability has stopped at lower order comparatively. Furthermore, considering production on a industrial scale, prolonged annealing processing is needed again for graphitization, and heat treatment cost is high.
[0005]
[Problem(s) to be Solved by the Invention] this invention is what conquered advantageously the problem in a conventional method which was mentioned above, and even if it reduces the content of Si, if possible, it aims at proposing the carbon steel for machine structures which made the machinability which closed, and had and was excellent not only in shortening of graphitization time but detailed-ization of the graphite grain after graphitization, and formability in cold forging combine.
[0006]
[Means for Solving the Problem] Now, in order to solve the above-mentioned technical problem, when this invention persons examined the graphitization behavior of the cementite in steel, they came to acquire the following knowledge. That is, the graphitization of a cementite advances by the process of crystallization of the diffusion -> graphite of C in the decomposition -> ferrite of a cementite. Addition of the element which dissolves in a ferrite rather than cementites, such as Si, nickel, Cu, and Co, to decomposition of a cementite is effective. Moreover, to crystallization of a graphite, nitrides, such as ALN and BN, are effective and graphitization is promoted by making these into a nucleus. and ** -- if many nitrides used as the nucleus of crystallization of a graphite [like] are made

to form, though alloy elements, such as Si which promotes decomposition of a cementite, will be reduced, graphitization is promoted remarkably Why these nitrides act as a nucleus of crystallization of a graphite is presumed because the crystal structure is similar with the graphite although not solved clearly yet.
[0007] Moreover, by making such a nitride form beforehand, the graphite particle size after graphitization also combined that grain refining was carried out remarkably, and it graphitization is not only promoted, but was found out. And the knowledge of formability in cold forging and machinability improving was acquired, so that the particle size of a graphite was detailed, when the relation between the particle size of a graphite, formability in cold forging, and machinability was considered. this invention is based on the above-mentioned knowledge.
[0008] That is, the summary composition of this invention is as follows.
1) C:0.1 - 1.5 mass% Less than [Si:0.5 mass%], Mn: 0.1 - 2.0 mass% aluminum:0.01 - 0.5 mass%, B:0.0003 - 0.0150mass%, and N:0.0015 - 0.0150mass %, Less than [O:0.0030mass%] is included. And nickel:0.1 - 3.0 mass%, One sort chosen from from while of Co:0.1 - 3.0 mass%, or two sorts or more are contained Cu:0.1 - 3.0 mass%. The remainder is the steel for machine structural use (the 1st invention) excellent in the machinability and formability in cold forging to which it becomes composition of Fe substantially and a metal texture is moreover characterized by the bird clapper more mainly than a ferrite and a graphite.
[0009] 2) Set to the 1st above-mentioned invention and it is Cr:0.05 - 1.0 mass% further. Steel for machine structural use excellent in the machinability and formability in cold forging which made one sort chosen from from while of Mo:0.05 - 0.5 mass%, or two sorts contain (the 2nd invention).
[0010] 3) Set to the 1st above-mentioned invention and it is further V:0.05 - 0.5 mass%. Steel for machine structural use excellent in the machinability and formability in cold forging which made at least one sort chosen from from while of Nb:0.005 -0.05mass%Ti:0.005 - 0.05mass% contain (the 3rd invention).
[0011] 4) Set to the 1st above-mentioned invention and it is Cr:0.05 - 1.0 mass% further. One sort chosen from from while of Mo:0.05 - 0.5 mass% or two sorts, and V:0.05 - 0.5 mass% Steel for machine structural use excellent in the machinability and formability in cold forging which made at least one sort chosen from from while of Nb:0.005 -0.05mass%Ti:0.005 - 0.05mass% contain (the 4th invention).
[0012] As opposed to the steel of any one publication of the 1st invention - the 4th invention 5) Further S:0.005 - 0.25mass%, and P:0.005 - 0.15mass %, Se: 0.003 - 0.10mass% and calcium:0.0002 - 0.30mass%, Te: The steel for machine structural use excellent in the machinability and formability in cold forging which make it come to contain one sort or two sorts or more of improvement elements in machinability chosen from from 0.002 - 0.5 mass% while of Pb:0.03 - 0.30mass% and Bi:0.01 - 0.3 mass% (the 5th invention).
[0013]
[Function] Hereafter, in this invention, the reason which limited component composition of steel to the above-mentioned range is explained.
C: 0.1 -1.5 mass%C is not only indispensable but [when forming a graphite phase,] a component indispensable when securing the intensity as a machine part. However, a content Such a graphite phase sufficient less than [0.1mass%] is not formed, but it is one side that machinability is raised. Since formability in cold forging fell when contained exceeding 1.5mass%, it limited to the range of 0.1 - 1.5 mass%.
[0014] Si: Less than [0.5 mass%] Si is an element which promotes the graphitization of a cementite. Moreover, since it is effective also as deoxidation material but on the other hand there is disadvantage the ductility of the ferrite phase after graphitization is reduced and formability in cold forging is reduced, from the field of an improvement of formability in cold forging, too much a lot of addition takes into consideration the above-mentioned profits and disadvantageous profit preferably, and it is at this invention. It is made to contain in below 0.5mass%.
[0015] Mn: Intensity although it is a component effective when securing the intensity as a machine part, to the extent that it goes by addition below 0.1mass% satisfactorily is not obtained, but 0.1 -2.0 mass%Mn is one side. Since the deformation resistance after graphitization went up when 2.0mass% was exceeded, it limited to the range of 0.1 - 2.0 mass%.
[0016] aluminum: Although it uses positively since it combines with N, AlN is formed and it acts effectively as a nucleus of crystallization of a graphite while it is powerful deoxidation material, it is deficient in the effect less than [0.01mass%], and 0.01-0.5 mass % aluminum is one side. Since the effect reaches saturation, it makes contain in 0.01 - 0.5 mass%, even if it adds exceeding 0.5mass%.
[0017] B: By combining with N and forming BN, since this serves as a nucleus of graphite crystallization and promotes graphitization, add 0.0003-0.0150mass%B positively. Moreover, B is an element contributed also to improvement in hardenability, and when securing the intensity as a machine part by hardening / tempering processing, it is useful. However, since the crack of a cast piece was promoted at the time of continuation forging

when the content was deficient in the addition effect less than [0.0003mass%] and added exceeding 0.0150mass (es)% on the other hand, it limited to the range of 0.0003 - 0.0150mass%.
[0018] O: Since a hard nonmetallic inclusion is formed into steel and formability in cold forging and machinability are degraded, although decreasing as much as possible is desirable, less than [0.0030mass%] O is permitted if it is to 0.0030mass%.
[0019] nickel: 0.1 - 3.0 mass% and Cu:0.1 - 3.0 mass%, Co:0.1 -3.0 mass%nickel, and Cu and Co, Since there is an advantage which it not only contributes in favor of promotion of graphitization, but [when all promote decomposition of a cementite,] does not check the ductility of a ferrite phase like Si even if it dissolves in a ferrite phase, and does not injure formability in cold forging since the dissolution potentiation is also weaker than Si, it adds positively. however, any -- content if it does not fill to 0.1mass% -- the addition effect -- scarce -- on the other hand -- since the effect reaches saturation even if it makes it contain exceeding 3.0mass% -- respectively -- It is made to contain in 0.1 - 3.0 mass%.
[0020] As mentioned above, although the fundamental component was explained, in this invention, the following elements can also be added further.
Cr:0.05 - 1.0 mass% and Mo:0.05 - 0.5 mass% -- they are equal as an improvement element of hardenability, and Cr and Mo are useful when securing the intensity as a machine part by hardening / tempering processing However, these elements also have the work which a cementite is stabilized [work] and delays graphitization. Therefore, on the occasion of addition of these elements, an effect is in the improvement in hardenability, and it needed to add in the range which does not check graphitization by one side, and limited to the range of Mo:0.05 - 0.5 mass% Cr:0.05 - 1.0mass% from this viewpoint, respectively.
[0021] V:0.05 - 0.5 mass%, Nb:0.005 - 0.05mass%, each of Ti:0.005 - 0.05mass%V, and Nb(s) and Ti combine with N, form a nitride, and they also have the operation which promotes detailed-ization of a graphite at the same time they aim at promotion of graphitization, when these act as a nucleus of graphite crystallization at the time of graphitization. Moreover, these elements form detailed carbide and contribute it also to improvement in intensity by the precipitation strengthening. then, the member which is hard to harden when there is the need of making a graphite grain more detailed when these elements have the need of making graphitization speed quicker, when securing without depending the intensity as a machine part on hardening / tempering processing, or when securing the intensity required of a large-sized machine part by QT -- when there is the need of making the intensity of a core increasing further, it uses Although a content considers as the range of Ti:0.005 - 0.05mass% Nb:0.005 - 0.05mass% V:0.05 - 0.5 mass%, respectively the lower limit of each element described above -- it is specified from the minimum amount required in order to acquire an effect, and on the other hand, the amount of graphites formed into steel decreases, and a upper limit is specified from the permissible upper limit which does not cause the fall of machinability, as a result of the amount of formation of carbide increasing by addition
[0022] In addition, in this invention, S generally known as an improvement element in machinability, P, Se, calcium, Te, Pb, etc. can be added further.
P: Although 0.005 -0.15mass%P is a useful element which raises machinability by stiffening a ferrite layer, it is also the element which checks graphitization by one side. Since graphitization was checked, consequently the fall of machinability was conversely caused when 0.005 mass% needs to be added at least for the improvement in machinability and it added exceeding 0.15mass(es)% on the other hand, it limited to the range below 0.15mass%.
[0023] S: 0.005 -0.25mass%S forms MnS, and it promotes graphitization by the bird clapper in the nucleus of graphitization while this acts as a chip breaker at the time of cutting and raises machinability. Consequently, although it added positively since machinability was raised further, less than [0.005 mass%], it was deficient in the addition effect, and since the effect was saturated on the other hand even if it made it contain exceeding 0.25mass%, it limited to the range of 0.005 - 0.25mass%.
[0024] Se: Since machinability is further raised by combining with Mn, MnSe's serving as a nucleus of graphitization at the same time this acts as a chip breaker and raises machinability by forming MnSe, and promoting graphitization, add 0.003 -0.10mass%Se positively. However, since the effect was saturated with less than [0.003 mass%] when the effect of the above [the addition] was small and exceeded 0.10mass% on the other hand, it limited to the range of 0.003 - 0.10mass%.
[0025] calcium: 0.0002-0.30mass%calcium forms the oxide of calcium system, and this acts as a nucleus of graphitization and it promotes graphitization. Moreover, it combines with MnS, and since it contributes to improvement in machinability by making the deposit gestalt of MnS into a spindle shape, it adds positively. However, the addition was deficient in the addition effect less than [0.0002mass%], and on the other hand, since many oxide system nonmetallic objects were formed and this reduced the fatigue strength as a machine part when it added exceeding 0.30mass%, it limited to the range of 0.0003 - 0.30mass%.

[0026] Te: Although it uses positively since MnTe is formed, this acts as a chip breaker and machinability is raised, since 0.002 -0.5 mass%Te is an element which checks graphitization by one side, if it adds so much, it will degrade machinability conversely. Then, while the contribution to the improvement in machinability was accepted, the prevention to graphitization carried out to making it contain by 0.002 which is not accepted notably - 0.5 mass% of within the limits.
[0027] Pb: Although the melting point was the element which for a low reason fuses by generation of heat of the steel materials at the time of cutting, and raises machinability according to the fluid lubrication effect, since there was also an operation which graphitization is checked by one side and reduces machinability conversely, 0.03-0.3 mass%Pb took both properties into consideration, and limited them to the range of 0.03 - 0.30mass%.
[0028] Bi: Although 0.01-0.30mass%Bi had the operation which the melting point fuses [operation] by generation of heat of the steel materials at the time of cutting like Pb for a low reason, and raises machinability according to the fluid lubrication effect, since graphitization is checked by one side and machinability was reduced conversely, it took both properties into consideration and limited them to the range of 0.01 - 0.30mass%.
[0029] Moreover, in this invention, not only component composition but a metal texture is important, and mainly needs to consider as the organization of a ferrite and a graphite. It is because it is conditions indispensable to this invention that the temperature rise of a cutting tool tends to be suppressed by the lubrication action of a graphite at the time of cutting, and it is going to raise the life of a cutting tool by that cause. The suitable content of the amount of graphites [here] in steel is 0.1 - 1.2 %. For that purpose, it is graphitization processing. The processing held in the temperature field of 600 - 750 ** for 5 to 20 hours is required. In addition, in this graphitization processing, hardening as pretreatment is unnecessary.
[0030] in addition -- since hot-working nature deteriorates when the above-mentioned improvement element in machinability is added -- heating of about 1000 degrees C or more -- and -- It is desirable to perform hot rolling of 850 degrees C or more. And it is more desirable above-mentioned to be within the limits and to lengthen the processing time, when the element which checks graphitization, such as Te, P, Bi, and Pb, especially is independently added as this improvement element in machinability, although it was possible to have made the temperature field of one or less Ac fully graphitize only by holding for about 5 to 30 hours as heat treatment of graphitization.
[0031]
[Example]
Example 1 table 1, After carrying out the convertor ingot and using as the bloom the steel materials which become the component composition shown in Table 2 by continuous casting, it considered as the steel bar of 35mmphi with steel bar rolling. Subsequently, 700 degree C and 19h graphitization processing were performed. The hardness, the amount of graphites, and graphite particle size of the steel materials obtained in this way were measured with image-analysis equipment. Moreover, the ratio with the amount of graphites when all of the measured amount of graphites and added C graphitize defined the rate of graphitization. Furthermore, the machinability examination and the cold-forging examination were performed. The machinability examination used the high speed tool steel SKH4, and the conditions of periphery lathe turning performed it here. The slitting depth and the feed per revolution at the time of cutting are each. It is 2.0mm and 0.25mm/rev. and time until cutting becomes impossible was defined as the tool life. Moreover, the compression test performed the cold-forging examination using the test piece of the shape of a pillar of 15mmphix22.5mml. While computing the deformation resistance from the deformation load at the time of compression, the crack generated on the test piece side after an examination was checked by viewing, and the compressibility which a crack generates in the moiety of a test piece was made into the critical upsetting ratio. The obtained test result is shown in Table 3.
[0032]
[Table 1]

[0033]
[Table 2]

No.	化学組成 (mass%)																備考
	C	Si	Mn	Al	B	N	O	Ni	Cu	Co	Cr	Mo	V	Nb	Ti	Pb	
1	0.14	0.39	1.79	0.019	0.0038	0.0042	0.0007	0.51	—	—	—	—	—	—	0.005	—	第3発明
2	0.37	0.47	1.21	0.018	0.0042	0.0083	0.0015	—	0.36	—	—	—	—	—	—	—	第1発明
3	0.53	0.24	0.44	0.016	0.0039	0.0075	0.0018	0.53	—	—	—	—	—	—	—	—	〃
4	0.75	—	0.44	0.017	0.0038	0.0136	0.0024	0.39	0.37	—	—	—	—	—	—	—	〃
5	1.03	0.45	0.36	0.021	0.0128	0.0098	0.0029	—	—	0.73	—	—	—	—	0.040	—	第3発明
6	1.33	0.09	0.75	0.019	0.0031	0.0021	0.0013	0.44	—	0.43	—	—	—	—	—	—	第1発明
7	0.54	0.21	0.42	0.035	0.0034	0.0082	0.0012	1.58	—	—	0.26	—	—	—	—	—	第2発明
8	0.53	0.18	0.45	0.046	0.0038	0.0085	0.0014	1.01	—	—	—	0.33	—	—	—	—	〃
9	0.53	0.19	0.45	0.028	0.0036	0.0083	0.0016	1.28	—	—	—	—	0.21	—	0.025	—	第3発明
10	0.54	0.21	0.45	0.087	0.0025	0.0085	0.0019	1.12	0.53	0.81	—	—	—	0.23	0.023	—	〃
11	0.53	0.48	0.33	0.068	0.0033	0.0083	0.0018	1.11	—	—	0.36	—	—	0.22	0.022	—	第4発明
12	0.53	0.49	0.41	0.075	0.0032	0.0082	0.0019	1.40	0.53	—	—	0.32	0.19	0.19	0.023	—	〃
13	0.54	0.55	0.41	0.019	0.0046	0.0081	0.0016	0.91	—	0.33	0.20	0.22	0.18	—	—	—	〃

[0034]
[Table 3]

No.	化学組成 (mass%)																備考
	C	Si	Mn	Al	B	N	O	Ni	Cu	Co	Cr	Mo	V	Nb	Ti	Pb	
14	0.14	0.75	1.79	0.019	0.0038	0.0042	0.0007	–	–	–	–	–	–	–	0.005	–	比較鋼
15	0.37	0.86	1.21	0.018	0.0042	0.0083	0.0015	–	0.36	–	–	–	–	–	–	–	〃
16	0.53	0.89	0.44	0.016	0.0039	0.0075	0.0018	0.53	–	–	–	–	–	–	–	–	〃
17	0.75	0.97	0.44	0.017	0.0038	0.0136	0.0024	0.39	0.37	–	–	–	–	–	–	–	〃
18	1.03	1.10	0.36	0.021	0.0128	0.0098	0.0029	–	–	–	–	–	–	–	0.040	–	〃
19	1.33	1.23	0.75	0.019	0.0031	0.0021	0.0013	0.44	–	0.43	–	–	–	–	–	–	〃
20	0.54	1.45	0.42	0.035	0.0034	0.0082	0.0012	1.58	–	–	0.26	–	–	–	–	–	〃
21	0.53	1.85	0.45	0.046	0.0038	0.0085	0.0014	1.01	–	–	–	0.33	–	–	–	–	〃
22	0.53	1.96	0.45	0.028	0.0036	0.0083	0.0016	1.28	–	–	–	–	0.21	–	0.025	–	〃
23	0.54	1.35	0.45	0.087	0.0025	0.0085	0.0019	1.12	0.53	0.81	–	–	–	0.23	0.023	–	〃
24	0.53	1.25	0.33	0.068	0.0033	0.0083	0.0018	1.11	–	–	0.36	–	–	0.22	0.022	–	〃
25	0.53	0.65	0.41	0.075	0.0032	0.0082	0.0019	1.40	0.53	–	–	0.32	0.19	0.19	0.023	–	〃
26	0.54	0.75	0.41	–	0.0046	0.0081	0.0016	0.91	–	0.33	0.20	0.22	0.18	–	–	0.07	〃
27	0.06	0.18	1.79	0.045	0.0012	0.0104	0.0025	–	–	–	–	–	–	–	–	–	〃
28	0.52	0.25	2.38	0.023	0.0001	0.0036	0.0019	–	–	–	–	–	–	–	–	–	〃
29	0.51	0.29	0.78	–	0.0022	0.0075	0.0021	–	–	–	–	–	–	–	–	–	〃
30	0.54	0.31	0.82	–	0.0034	0.0018	0.0042	–	–	–	–	–	–	–	–	–	〃
31	0.55	0.21	1.31	–	0.0035	0.0175	0.0019	–	–	–	–	–	–	–	–	–	〃
32	0.53	0.22	0.86	0.025	0.0001	0.0073	0.0015	–	–	–	–	–	–	–	–	0.35	〃
33	0.25	0.24	0.58	0.027	0.0001	0.0081	0.0017	–	–	–	–	–	–	–	–	0.36	〃

供試材 No.	黒鉛化率 (%)	黒鉛粒径 (μm)	硬さ (Hv)	変形抵抗 (MPa)	限界圧縮率 (%)	工具寿命 (min)	備　考
1	100	11	193.1	737.8	77.3	40.3	第3発明
2	100	13	191.9	735.5	78.2	52.9	第1発明
3	100	14	200.3	724.2	78.2	62.6	〃
4	100	19	218.2	718.8	80.5	68.2	〃
5	100	20	150.5	729.3	80.5	93.1	第3発明
6	100	36	217.7	723.0	87.8	83.4	第1発明
7	100	13	236.9	723.5	77.6	61.8	第2発明
8	100	13	237.7	723.0	77.9	60.2	〃
9	100	12	307.0	730.0	77.1	56.2	第3発明
10	100	7	241.3	782.1	74.8	70.5	〃
11	100	6	265.3	785.4	74.2	69.0	第4発明
12	100	5	365.3	784.0	74.1	60.6	〃
13	100	12	294.1	736.6	77.1	58.0	〃
14	100	11	175.6	746.1	77.2	42.3	比較鋼
15	100	12	183.4	744.5	77.6	55.4	〃
16	100	12	186.1	739.3	77.3	66.8	〃
17	100	16	197.0	741.4	79.2	74.5	〃
18	100	18	160.5	744.4	79.6	95.1	〃
19	100	33	192.7	749.5	86.3	90.8	〃
20	100	9	209.7	752.3	75.9	69.8	〃
21	100	8	201.1	761.9	75.6	71.0	〃
22	100	6	268.2	771.3	74.7	67.6	〃
23	100	3	216.3	808.7	73.2	77.8	〃
24	100	3	248.5	802.4	73.2	74.2	〃
25	100	5	361.8	787.8	73.8	61.6	〃
26	100	11	289.8	741.2	76.9	62.0	〃
27	41	11	193.3	869.3	70.7	31.9	〃
28	33	26	213.6	892.8	76.5	17.5	〃
29	41	17	195.8	864.4	72.8	36.1	〃
30	46	17	193.0	852.4	73.8	38.1	〃
31	43	19	198.4	861.4	74.1	34.4	〃
32	—	—	204.7	—	—	19.0	〃
33	—	—	193.5	—	—	25.0	〃

[0035] Front Naka and No.1-13 are the 1st - the 4th invention steel. moreover -- No.14-26 are the steel which raised No.1-13 to Si out of range [this invention]. Further No.26-31 are the steel with which components other than Si deviated from the proper range of this invention. in addition -- No. -- 32 and 33 are the free cutting steels which added Pb to JIS S25C and JIS S45C Although each No.1-26 excels Pb free cutting steel in machinability, it reaches No.1-13, so that clearly from Table 3. Deformation resistances are all if No.14-26 are compared. No.14-26 are higher and it is inferior to formability in cold forging compared with No.1-13 which are invention steel. moreover -- It is low, therefore a deformation resistance is remarkable, and No.27-31 have a high rate of graphitization. Although machinability is superior to Pb free cutting steel, it is less than this invention steel.

[0036] Example 2 table 4, Steel (improvement element addition steel in machinability) of a chemical composition shown in Table 5 was used as 52mmphi steel bar like the example 1. Rate of graphitization of the obtained steel materials, Graphite particle size, The investigated result is collectively shown in Table 6 about hardness and a tool life. Sample offering steel No.1-13 are the example of the 5th invention steel. Moreover, No.14-26 remove improvement elements in machinability, such as Pb which is an indispensable component, Bi, and Te, calcium, from invention steel. No.27-28 have an indispensable alloying element for graphitization out of range in this invention. Furthermore, it reaches No.29 and 30 is JIS. It is Pb free cutting steel which added Pb, Bi, and Te to the carbon steel for machine structures. If not only a tool life is high, but comparison steel No.14-26 are compared with this invention steel and the direction of this invention steel compares it with steel conventionally, the tool life will improve extremely. Furthermore, although it is lower order on the whole compared with comparison steel No.14-26, the rates of graphitization of this invention steel are because [, such as this and 700 degree-Cx10h,] a short time was processed comparatively, and if the processing time is extended to about 30h as mentioned above, they can aim at much more improvement in a life. Comparison steel No.27 and 28 have a very low rate of graphitization to a low sake, and the tool life is inferior to machinability.

[0037]

[Table 4]

[0038]
[Table 5]

No	化学組成 (mass%)																					区分
	C	Si	Mn	Al	B	N	O	Ni	Cu	Co	Cr	Mo	V	Nb	Ti	P	S	Pb	Bi	Te	Ca	Se	
1	0.14	0.39	1.79	0.015	0.0038	0.0042	0.0007	0.51	–	–	–	–	–	–	0.005	0.006	0.008	0.08	0.09	–	–	–	第5発明鋼
2	0.37	0.47	1.21	0.019	0.0042	0.0083	0.0015	–	0.36	–	–	–	–	–	–	0.015	0.015	–	0.19	0.04	–	–	
3	0.53	0.24	0.44	0.018	0.0039	0.0075	0.0018	0.53	–	–	–	–	–	–	–	0.007	0.023	–	0.09	–	–	0.042	
4	0.75	0.38	0.44	0.006	0.0038	0.0136	0.0024	0.39	0.37	–	–	–	–	–	–	0.019	0.205	–	0.18	0.42	–	0.012	
5	1.03	0.45	0.36	0.012	0.0128	0.0098	0.0029	–	–	0.73	–	–	–	–	0.040	0.017	0.214	0.16	0.28	0.18	–	0.041	
6	1.33	0.09	0.75	0.017	0.0031	0.0021	0.0013	0.44	–	0.43	–	–	–	–	–	0.016	0.018	0.08	0.09	–	–	–	
7	0.54	0.21	0.42	0.015	0.0034	0.0082	0.0012	1.58	–	–	0.26	–	–	–	–	0.019	0.055	–	0.18	–	–	0.087	
8	0.53	0.18	0.45	0.014	0.0038	0.0085	0.0014	1.01	–	–	–	0.33	–	–	–	0.045	0.015	0.24	0.31	–	0.018	0.025	
9	0.53	0.19	0.45	0.019	0.0036	0.0083	0.0016	1.28	–	–	–	–	0.21	–	0.025	0.026	0.018	0.09	–	0.32	0.125	0.084	
10	0.54	0.21	0.45	0.018	0.0025	0.0085	0.0019	1.12	0.53	0.81	–	–	–	0.23	0.023	0.019	0.022	0.15	0.24	0.22	0.017	0.042	
11	0.53	0.48	0.33	0.015	0.0033	0.0083	0.0018	1.11	–	–	0.36	–	–	0.22	0.022	0.067	0.098	–	–	0.38	–	0.087	
12	0.53	0.49	0.41	0.016	0.0032	0.0082	0.0019	1.40	0.53	–	–	0.32	0.19	0.19	0.023	0.072	0.145	–	0.18	0.42	–	0.012	
13	0.54	0.55	0.41	0.019	0.0046	0.0081	0.0016	0.91	–	0.33	0.20	0.22	0.18	–	–	0.006	0.002	0.07	–	–	–	–	

[0039]
[Table 6]

No.	化学組成 (mass%)																					区分
	C	Si	Mn	Al	B	N	O	Ni	Cu	Co	Cr	Mo	V	Nb	Ti	P	S	Pb	Bi	Te	Ca	Se	
14	0.14	0.39	1.79	0.014	0.0038	0.0042	0.0006	0.51	–	–	–	–	–	–	0.005	–	–	–	–	–	–	–	比較鋼
15	0.37	0.47	1.21	0.018	0.0042	0.0083	0.0015	–	0.36	–	–	–	–	–	–	–	–	–	–	–	–	–	
16	0.53	0.24	0.44	0.007	0.0039	0.0075	0.0023	0.53	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
17	0.75	0.38	0.44	0.018	0.0038	0.0136	0.0025	0.39	0.37	–	–	–	–	–	–	–	–	–	–	–	–	–	
18	1.03	0.45	0.36	0.016	0.0128	0.0098	0.0017	–	–	0.73	–	–	–	–	0.040	–	–	–	–	–	–	–	
19	1.33	0.09	0.75	0.017	0.0031	0.0021	0.0018	0.44	–	0.43	–	–	–	–	–	–	–	–	–	–	–	–	
20	0.54	0.21	0.42	0.016	0.0034	0.0082	0.0022	1.58	–	–	0.26	–	–	–	–	–	–	–	–	–	–	–	
21	0.53	0.18	0.45	0.018	0.0038	0.0085	0.0014	1.01	–	–	–	0.33	–	–	–	–	–	–	–	–	–	–	
22	0.53	0.19	0.45	0.016	0.0036	0.0083	0.0015	1.28	–	–	–	–	0.21	–	0.025	–	–	–	–	–	–	–	
23	0.54	0.21	0.45	0.019	0.0025	0.0085	0.0012	1.12	0.53	0.81	–	–	–	–	0.023	–	–	–	–	–	–	–	
24	0.53	0.48	0.33	0.018	0.0033	0.0083	0.0022	1.11	–	–	0.36	–	–	–	0.022	–	–	–	–	–	–	–	
25	0.53	0.49	0.41	0.017	0.0032	0.0082	0.0015	1.40	0.53	–	–	0.32	0.19	–	0.023	–	–	–	–	–	–	–	
26	0.54	0.28	0.41	0.016	0.0046	0.0081	0.0021	0.91	–	0.33	0.20	0.22	0.18	–	–	–	–	–	–	–	–	–	
27	0.53	0.18	0.83	0.018	0.0036	0.0104	0.0025	–	–	–	–	–	–	–	–	0.001	0.004	–	–	–	–	–	
28	0.51	0.29	0.78	0.019	0.0002	0.0075	0.0021	0.42	–	–	–	–	–	–	–	0.001	0.004	–	–	–	–	–	
29	0.53	0.22	0.86	0.025	0.0001	0.0073	0.0015	–	–	–	–	–	–	–	–	0.012	0.016	0.35	–	–	–	–	
30	0.25	0.24	0.58	0.026	0.0001	0.0081	0.0017	–	–	–	–	–	–	–	–	0.011	0.015	0.36	–	–	–	–	

供試材 No.	黒鉛化率 (%)	黒鉛粒径 (μm)	硬さ (Hv)	変形抵抗 (MPa)	限界圧縮率 (%)	工具寿命 (min)	備　考
1	65	13	186.4	818.3	72.3	43.9	第5発明
2	53	14	193.8	845.9	71.2	53.5	〃
3	63	16	158.9	822.9	71.0	55.1	〃
4	52	22	141.7	848.2	74.8	63.2	〃
5	100	33	190.4	737.8	74.9	109.3	〃
6	61	15	205.2	827.5	79.6	90.2	〃
7	82	13	202.9	779.2	72.5	70.7	〃
8	52	14	197.0	848.2	72.6	76.0	〃
9	72	10	236.4	802.2	73.1	64.4	〃
10	100	11	186.3	737.8	71.2	100.1	〃
11	61	10	199.2	827.5	69.4	62.0	〃
12	77	10	292.3	790.7	68.4	72.5	〃
13	97	14	181.4	744.7	69.2	66.8	〃
14	68	13	184.6	811.4	72.3	34.6	比較鋼
15	58	14	193.8	834.4	71.2	40.5	〃
16	63	16	158.9	822.9	71.1	48.8	〃
17	54	22	141.7	843.6	73.9	46.9	〃
18	100	33	190.4	737.8	73.5	83.6	〃
19	68	15	205.2	811.4	75.0	86.9	〃
20	88	13	202.9	765.4	78.3	60.1	〃
21	76	14	197.0	793.0	71.2	53.4	〃
22	85	10	236.4	772.3	71.3	60.1	〃
23	100	11	186.3	737.8	72.0	74.5	〃
24	80	10	199.2	783.8	69.9	60.5	〃
25	100	10	292.3	737.8	68.9	60.8	〃
26	89	14	181.4	763.1	72.3	61.1	〃
27	45	41	206.0	864.3	73.8	41.8	〃
28	48	46	204.3	857.4	73.9	42.3	〃
29	—	—	193.7	—	—	19.0	〃
30	—	—	193.7	—	—	25.0	〃

[0040]
[Effect of the Invention] In this way, according to this invention, the deformation resistance at the time of cold forging is low, and is **(ing) [can obtain easily the steel materials which were simultaneously excellent in machinability, and]-to manufacture of machine part size.

[Translation done.]

TECHNICAL FIELD

[Industrial Application] this invention means improvement in the machinability and formability in cold forging especially about the carbon steel for machine structures used as a material of machine parts, such as an industrial machine and an automobile.

[Translation done.]

PRIOR ART

[Description of the Prior Art] After machine parts, such as an industrial machine and an automobile, are made from the carbon steel for machine structures, or alloy steel and are generally fabricated by the predetermined configuration through cold forging or a cutting process, in order to secure the intensity as a machine part, hardening and tempering processing are performed and let them be products. Therefore, from this kind of steel materials, formability in cold forging is required simultaneously with machinability.

[0003] The method of adding free-cutting elements, such as Pb, S, Bi, Te, and calcium, to steel materials, and making a nonmetallic inclusion form into steel as a method of improving the machinability of steel materials is well-known. On the other hand, reducing the nonmetallic inclusion in steel contrary to the case of machinability as a means to improve the deformability at the time of formability in cold forging, especially cold forging is performed. Therefore, machinability and formability in cold forging were very difficult for reconciling these, though it is the property always demanded from steel-for-machine-structural-use material, such as an industrial machine and autoparts, and there was a problem that a sacrifice fake colander was not obtained, about one of properties.

[0004] As a solution of the above-mentioned problem, the steel materials which raised formability in cold forging and machinability simultaneously are proposed by graphitizing the cementite in steel by JP,51-57621,A. However, according to examination of this invention persons, it has left the problem described below. That is, Si content by the above-mentioned method Since it is high, although graphitization completes the cementite in steel early comparatively with 1.9 - 3.0 mass%, in order that Si may dissolve in a ferrite phase and may reduce the deformability of a ferrite, the deformability at the time of cold forging falls, and its deformation resistance at the time of cold forging is also high by solid-solution-strengthening operation of Si. Moreover, by this method, the graphite particle size after graphitization accumulated greatly, and the improvement of the deformability in cold forging and machinability has stopped at lower order comparatively. Furthermore, considering production on a industrial scale, prolonged annealing processing is needed again for graphitization, and heat treatment cost is high.

EFFECT OF THE INVENTION

[Effect of the Invention] In this way, according to this invention, the deformation resistance at the time of cold forging is low, and is **(ing) [can obtain easily the steel materials which were simultaneously excellent in machinability, and]-to manufacture of machine part size.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] this invention is what conquered advantageously the problem in a conventional method which was mentioned above, and even if it reduces the content of Si, if possible, it aims at proposing the carbon steel for machine structures which made the machinability which closed, and had and was excellent not only in shortening of graphitization time but detailed-ization of the graphite grain after graphitization, and formability in cold forging combine.

[Translation done.]

MEANS

[Means for Solving the Problem] Now, in order to solve the above-mentioned technical problem, when this invention persons examined the graphitization behavior of the cementite in steel, they came to acquire the following knowledge. That is, the graphitization of a cementite advances by the process of crystallization of the diffusion -> graphite of C in the decomposition -> ferrite of a cementite. Addition of the element which dissolves in a ferrite rather than cementites, such as Si, nickel, Cu, and Co, to decomposition of a cementite is effective. Moreover, to crystallization of a graphite, nitrides, such as ALN and BN, are effective and graphitization is promoted by making these into a nucleus. and ** -- if many nitrides used as the nucleus of crystallization of a graphite [like] are made to form, though alloy elements, such as Si which promotes decomposition of a cementite, will be reduced, graphitization is promoted remarkably Why these nitrides act as a nucleus of crystallization of a graphite is presumed because the crystal structure is similar with the graphite although not solved clearly yet.
[0007] Moreover, by making such a nitride form beforehand, the graphite particle size after graphitization also combined that grain refining was carried out remarkably, and it graphitization is not only promoted, but was found out. And the knowledge of formability in cold forging and machinability improving was acquired, so that the particle size of a graphite was detailed, when the relation between the particle size of a graphite, formability in cold forging, and machinability was considered. this invention is based on the above-mentioned knowledge.
[0008] That is, the summary composition of this invention is as follows.
1) C:0.1 - 1.5 mass% Less than [Si:0.5 mass%], Mn: 0.1 - 2.0 mass% aluminum:0.01 - 0.5 mass%, B:0.0003 - 0.0150mass%, and N:0.0015 - 0.0150mass %, Less than [O:0.0030mass%] is included. And nickel:0.1 - 3.0 mass%, One sort chosen from from while of Co:0.1 - 3.0 mass%, or two sorts or more are contained Cu:0.1 - 3.0 mass%. The remainder is the steel for machine structural use (the 1st invention) excellent in the machinability and formability in cold forging to which it becomes composition of Fe substantially and a metal texture is moreover characterized by the bird clapper more mainly than a ferrite and a graphite.
[0009] 2) Set to the 1st above-mentioned invention and it is Cr:0.05 - 1.0 mass% further. Steel for machine structural use excellent in the machinability and formability in cold forging which made one sort chosen from from while of Mo:0.05 - 0.5 mass%, or two sorts contain (the 2nd invention).
[0010] 3) Set to the 1st above-mentioned invention and it is further V:0.05 - 0.5 mass%. Steel for machine structural use excellent in the machinability and formability in cold forging which made at least one sort chosen from from while of Nb:0.005 -0.05mass%Ti:0.005 - 0.05mass% contain (the 3rd invention).
[0011] 4) Set to the 1st above-mentioned invention and it is Cr:0.05 - 1.0 mass% further. One sort chosen from from while of Mo:0.05 - 0.5 mass% or two sorts, and V:0.05 - 0.5 mass% Steel for machine structural use excellent in the machinability and formability in cold forging which made at least one sort chosen from from while of Nb:0.005 -0.05mass%Ti:0.005 - 0.05mass% contain (the 4th invention).
[0012] As opposed to the steel of any one publication of the 1st invention - the 4th invention 5) Further S:0.005 - 0.25mass%, and P:0.005 - 0.15mass %, Se: 0.003 - 0.10mass% and calcium:0.0002 - 0.30mass%, Te: The steel for machine structural use excellent in the machinability and formability in cold forging which make it come to contain one sort or two sorts or more of improvement elements in machinability chosen from from 0.002 - 0.5 mass% while of Pb:0.03 - 0.30mass% and Bi:0.01 - 0.3 mass% (the 5th invention).

OPERATION

[Function] Hereafter, in this invention, the reason which limited component composition of steel to the above-mentioned range is explained.
C: 0.1 -1.5 mass%C is not only indispensable but [when forming a graphite phase,] a component indispensable when securing the intensity as a machine part. However, a content Such a graphite phase sufficient less than [0.1mass%] is not formed, but it is one side that machinability is raised. Since formability in cold forging fell when contained exceeding 1.5mass%, it limited to the range of 0.1 - 1.5 mass%.
[0014] Si: Less than [0.5 mass%] Si is an element which promotes the graphitization of a cementite. Moreover, since it is effective also as deoxidation material but on the other hand there is disadvantage the ductility of the ferrite phase after graphitization is reduced and formability in cold forging is reduced, from the field of an improvement of formability in cold forging, too much a lot of addition takes into consideration the above-mentioned profits and disadvantageous profit preferably, and it is at this invention. It is made to contain in below 0.5mass%.
[0015] Mn: Intensity although it is a component effective when securing the intensity as a machine part, to the extent that it goes by addition below 0.1mass% satisfactorily is not obtained, but 0.1 -2.0 mass%Mn is one side. Since the deformation resistance after graphitization went up when 2.0mass% was exceeded, it limited to the range of 0.1 - 2.0 mass%.
[0016] aluminum: Although it uses positively since it combines with N, AlN is formed and it acts effectively as a nucleus of crystallization of a graphite while it is powerful deoxidation material, it is deficient in the effect less than [0.01mass%], and 0.01-0.5 mass % aluminum is one side. Since the effect reaches saturation, it makes contain in 0.01 - 0.5 mass%, even if it adds exceeding 0.5mass%.
[0017] B: By combining with N and forming BN, since this serves as a nucleus of graphite crystallization and promotes graphitization, add 0.0003-0.0150mass%B positively. Moreover, B is an element contributed also to improvement in hardenability, and when securing the intensity as a machine part by hardening / tempering processing, it is useful. However, since the crack of a cast piece was promoted at the time of continuation forging when the content was deficient in the addition effect less than [0.0003mass%] and added exceeding 0.0150mass (es)% on the other hand, it limited to the range of 0.0003 - 0.0150mass%.
[0018] O: Since a hard nonmetallic inclusion is formed into steel and formability in cold forging and machinability are degraded, although decreasing as much as possible is desirable, less than [0.0030mass%] O is permitted if it is to 0.0030mass%.
[0019] nickel: 0.1 - 3.0 mass% and Cu:0.1 - 3.0 mass%, Co:0.1 -3.0 mass%nickel, and Cu and Co, Since there is an advantage which it not only contributes in favor of promotion of graphitization, but [when all promote decomposition of a cementite,] does not check the ductility of a ferrite phase like Si even if it dissolves in a ferrite phase, and does not injure formability in cold forging since a solid-solution-strengthening operation is also weaker than Si, it adds positively. however, any -- content if it does not fill to 0.1mass% -- the addition effect -- scarce -- on the other hand -- since the effect reaches saturation even if it makes it contain exceeding 3.0mass% -- respectively -- It is made to contain in 0.1 - 3.0 mass%.
[0020] As mentioned above, although the fundamental component was explained, in this invention, the following elements can also be added further.
Cr:0.05 - 1.0 mass% and Mo:0.05 - 0.5 mass% -- they are equal as an improvement element of hardenability, and Cr and Mo are useful when securing the intensity as a machine part by hardening / tempering processing However, these elements also have the work which a cementite is stabilized [work] and delays graphitization. Therefore, on the occasion of addition of these elements, an effect is in the improvement in hardenability, and it needed to add in the range which does not check graphitization by one side, and limited to the range of Mo:0.05 - 0.5 mass% Cr:0.05

- 1.0mass% from this viewpoint, respectively.
[0021] V:0.05 - 0.5 mass%, Nb:0.005 - 0.05mass%, each of Ti:0.005 - 0.05mass%V, and Nb(s) and Ti combine with N, form a nitride, and they also have the operation which promotes detailed-ization of a graphite at the same time they aim at promotion of graphitization, when these act as a nucleus of graphite crystallization at the time of graphitization. Moreover, these elements form detailed carbide and contribute it also to improvement in intensity by the precipitation strengthening. then, the member which is hard to harden when there is the need of making a graphite grain more detailed when these elements have the need of making graphitization speed quicker, when securing without depending the intensity as a machine part on hardening / tempering processing, or when securing the intensity required of a large-sized machine part by QT -- when there is the need of making the intensity of a core increasing further, it uses Although a content considers as the range of Ti:0.005 - 0.05mass% Nb:0.005 - 0.05mass% V:0.05 - 0.5 mass%, respectively the lower limit of each element described above -- it is specified from the minimum amount required in order to acquire an effect, and on the other hand, the amount of graphites formed into steel decreases, and a upper limit is specified from the permissible upper limit which does not cause the fall of machinability, as a result of the amount of formation of carbide increasing by addition
[0022] In addition, in this invention, S generally known as an improvement element in machinability, P, Se, calcium, Te, Pb, etc. can be added further.
P: Although 0.005 -0.15mass%P is a useful element which raises machinability by stiffening a ferrite layer, it is also the element which checks graphitization by one side. Since graphitization was checked, consequently the fall of machinability was conversely caused when 0.005 mass% needs to be added at least for the improvement in machinability and it added exceeding 0.15mass(es)% on the other hand, it limited to the range below 0.15mass%.
[0023] S: 0.005 -0.25mass%S forms MnS, and it promotes graphitization by the bird clapper in the nucleus of graphitization while this acts as a chip breaker at the time of cutting and raises machinability. Consequently, although it added positively since machinability was raised further, less than [0.005 mass%], it was deficient in the addition effect, and since the effect was saturated on the other hand even if it made it contain exceeding 0.25mass%, it limited to the range of 0.005 - 0.25mass%.
[0024] Se: Since machinability is further raised by combining with Mn, MnSe's serving as a nucleus of graphitization at the same time this acts as a chip breaker and raises machinability by forming MnSe, and promoting graphitization, add 0.003 -0.10mass%Se positively. However, since the effect was saturated with less than [0.003 mass%] when the effect of the above [the addition] was small and exceeded 0.10mass% on the other hand, it limited to the range of 0.003 - 0.10mass%.
[0025] calcium: 0.0002-0.30mass%calcium forms the oxide of calcium system, and this acts as a nucleus of graphitization and it promotes graphitization. Moreover, it combines with MnS, and since it contributes to improvement in machinability by making the deposit form of MnS into a spindle shape, it adds positively. However, the addition was deficient in the addition effect less than [0.0002mass%], and on the other hand, since many oxide system nonmetallic objects were formed and this reduced the fatigue strength as a machine part when it added exceeding 0.30mass%, it limited to the range of 0.0003 - 0.30mass%.
[0026] Te: Although it uses positively since MnTe is formed, this acts as a chip breaker and machinability is raised, since 0.002 -0.5 mass%Te is an element which checks graphitization by one side, if it adds so much, it will degrade machinability conversely. Then, while the contribution to the improvement in machinability was accepted, the prevention to graphitization carried out to making it contain by 0.002 which is not accepted notably - 0.5 mass% of within the limits.
[0027] Pb: Since the melting point was low, although 0.03-0.3 mass%Pb was an element which fuses by generation of heat of the steel materials at the time of cutting, and raises machinability according to the fluid lubrication effect, since there was also an operation which graphitization is checked by one side and reduces machinability conversely, it took both properties into consideration and limited them to the range of 0.03 - 0.30mass%.
[0028] Bi: Although 0.01-0.30mass%Bi had the operation which it fuses [operation] by generation of heat of the steel materials at the time of cutting, and raises machinability according to the fluid lubrication effect, since the melting point was low, and it checks graphitization by one side and reduced machinability conversely like Pb, it took both properties into consideration and limited them to the range of 0.01 - 0.30mass%.
[0029] Moreover, in this invention, not only component composition but a metal texture is important, and mainly needs to consider as the organization of a ferrite and a graphite. It is because it is conditions indispensable to this invention that the temperature rise of a cutting tool tends to be suppressed by the lubrication action of a graphite at the time of cutting, and it is going to raise the life of a cutting tool by that cause. The suitable content of the amount of graphites [here] in steel is 0.1 - 1.2 %. For that purpose, it is graphitization processing. The processing held in the temperature field of 600 - 750 ** for 5 to 20 hours is required. In addition, in this graphitization processing,

hardening as pretreatment is unnecessary.
[0030] in addition -- since hot-working nature deteriorates when the above-mentioned improvement element in machinability is added -- heating of about 1000 degrees C or more -- and -- It is desirable to perform hot rolling of 850 degrees C or more. And it is more desirable above-mentioned to be within the limits and to lengthen the processing time, when the element which checks graphitization, such as Te, P, Bi, and Pb, especially is independently added as this improvement element in machinability, although it was possible to have made the temperature field of one or less Ac fully graphitize only by holding for about 5 to 30 hours as heat treatment of graphitization.

[Translation done.]

EXAMPLE

[Example]
Example 1 table 1, After carrying out the convertor ingot and using as the bloom the steel materials which become the component composition shown in Table 2 by continuous casting, it considered as the steel bar of 35mmphi with steel bar rolling. Subsequently, 700 degree C and 19h graphitization processing were performed. The hardness, the amount of graphites, and graphite particle size of the steel materials obtained in this way were measured with image-analysis equipment. Moreover, the ratio with the amount of graphites when all of the measured amount of graphites and added C graphitize defined the rate of graphitization. Furthermore, the machinability examination and the cold-forging examination were performed. The machinability examination used the high speed tool steel SKH4, and the conditions of periphery lathe turning performed it here. The slitting depth and the feed per revolution at the time of cutting are each. It is 2.0mm and 0.25mm/rev. and time until cutting becomes impossible was defined as the tool life. Moreover, the compression test performed the cold-forging examination using the test piece of the shape of a pillar of 15mmphix22.5mml. While computing the deformation resistance from the deformation load at the time of compression, the crack generated on the test piece side after an examination was checked by viewing, and the compressibility which a crack generates in the half of a test piece was made into the critical upsetting ratio. The obtained test result is shown in Table 3.
[0032]
[Table 1]

[0033]
[Table 2]

No.	化学組成 (mass%)																備考
	C	Si	Mn	Al	B	N	O	Ni	Cu	Co	Cr	Mo	V	Nb	Ti	Pb	
1	0.14	0.39	1.79	0.019	0.0038	0.0042	0.0007	0.51	—	—	—	—	—	—	0.005	—	第3発明
2	0.37	0.47	1.21	0.018	0.0042	0.0083	0.0015	—	0.36	—	—	—	—	—	—	—	第1発明
3	0.53	0.24	0.44	0.016	0.0039	0.0075	0.0018	0.53	—	—	—	—	—	—	—	—	〃
4	0.75	—	0.44	0.017	0.0038	0.0136	0.0024	0.39	0.37	—	—	—	—	—	—	—	〃
5	1.03	0.45	0.36	0.021	0.0128	0.0098	0.0029	—	—	0.73	—	—	—	—	0.040	—	第3発明
6	1.33	0.09	0.75	0.019	0.0031	0.0021	0.0013	0.44	—	0.43	—	—	—	—	—	—	第1発明
7	0.54	0.21	0.42	0.035	0.0034	0.0082	0.0012	1.58	—	—	0.26	—	—	—	—	—	第2発明
8	0.53	0.18	0.45	0.046	0.0038	0.0085	0.0014	1.01	—	—	—	0.33	—	—	—	—	〃
9	0.53	0.19	0.45	0.028	0.0036	0.0083	0.0016	1.28	—	—	—	—	0.21	—	0.025	—	第3発明
10	0.54	0.21	0.45	0.087	0.0025	0.0085	0.0019	1.12	0.53	0.81	—	—	—	0.23	0.023	—	〃
11	0.53	0.48	0.33	0.068	0.0033	0.0083	0.0018	1.11	—	—	0.36	—	—	0.22	0.022	—	第4発明
12	0.53	0.49	0.41	0.075	0.0032	0.0082	0.0019	1.40	0.53	—	—	0.32	0.19	0.19	0.023	—	〃
13	0.54	0.55	0.41	0.019	0.0046	0.0081	0.0016	0.91	—	0.33	0.20	0.22	0.18	—	—	—	〃

[0034]
[Table 3]

No.	化学組成 (mass%)																備考
	C	Si	Mn	Al	B	N	O	Ni	Cu	Co	Cr	Mo	V	Nb	Ti	Pb	
14	0.14	0.75	1.79	0.019	0.0038	0.0042	0.0007	–	–	–	–	–	–	–	0.005	–	比較鋼
15	0.37	0.86	1.21	0.018	0.0042	0.0083	0.0015	–	0.36	–	–	–	–	–	–	–	〃
16	0.53	0.89	0.44	0.016	0.0039	0.0075	0.0018	0.53	–	–	–	–	–	–	–	–	〃
17	0.75	0.97	0.44	0.017	0.0038	0.0136	0.0024	0.39	0.37	–	–	–	–	–	–	–	〃
18	1.03	1.10	0.36	0.021	0.0128	0.0098	0.0029	–	–	–	–	–	–	–	0.040	–	〃
19	1.33	1.23	0.75	0.019	0.0031	0.0021	0.0013	0.44	–	0.43	–	–	–	–	–	–	〃
20	0.54	1.45	0.42	0.035	0.0034	0.0082	0.0012	1.58	–	–	0.26	–	–	–	–	–	〃
21	0.53	1.85	0.45	0.046	0.0038	0.0085	0.0014	1.01	–	–	–	0.33	–	–	–	–	〃
22	0.53	1.96	0.45	0.028	0.0036	0.0083	0.0016	1.28	–	–	–	–	0.21	–	0.025	–	〃
23	0.54	1.35	0.45	0.087	0.0025	0.0085	0.0019	1.12	0.53	0.81	–	–	–	0.23	0.023	–	〃
24	0.53	1.25	0.33	0.068	0.0033	0.0083	0.0018	1.11	–	–	0.36	–	–	0.22	0.022	–	〃
25	0.53	0.65	0.41	0.075	0.0032	0.0082	0.0019	1.40	0.53	–	–	0.32	0.19	0.19	0.023	–	〃
26	0.54	0.75	0.41	–	0.0046	0.0081	0.0016	0.91	–	0.33	0.20	0.22	0.18	–	–	0.07	〃
27	0.06	0.18	1.79	0.045	0.0012	0.0104	0.0025	–	–	–	–	–	–	–	–	–	〃
28	0.52	0.25	2.38	0.023	0.0001	0.0036	0.0019	–	–	–	–	–	–	–	–	–	〃
29	0.51	0.29	0.78	–	0.0022	0.0075	0.0021	–	–	–	–	–	–	–	–	–	〃
30	0.54	0.31	0.82	–	0.0034	0.0018	0.0042	–	–	–	–	–	–	–	–	–	〃
31	0.55	0.21	1.31	–	0.0035	0.0175	0.0019	–	–	–	–	–	–	–	–	–	〃
32	0.53	0.22	0.86	0.025	0.0001	0.0073	0.0015	–	–	–	–	–	–	–	–	0.35	〃
33	0.25	0.24	0.58	0.027	0.0001	0.0081	0.0017	–	–	–	–	–	–	–	–	0.36	〃

供試材 No.	黒鉛化率 (%)	黒鉛粒径 (μm)	硬さ (Hv)	変形抵抗 (MPa)	限界圧縮率 (%)	工具寿命 (min)	備　考
1	100	11	193.1	737.8	77.3	40.3	第3発明
2	100	13	191.9	735.5	78.2	52.9	第1発明
3	100	14	200.3	724.2	78.2	62.6	〃
4	100	19	218.2	718.8	80.5	68.2	〃
5	100	20	150.5	729.3	80.5	93.1	第3発明
6	100	36	217.7	723.0	87.8	83.4	第1発明
7	100	13	236.9	723.5	77.6	61.8	第2発明
8	100	13	237.7	723.0	77.9	60.2	〃
9	100	12	307.0	730.0	77.1	56.2	第3発明
10	100	7	241.3	782.1	74.8	70.5	〃
11	100	6	265.3	785.4	74.2	69.0	第4発明
12	100	5	365.3	784.0	74.1	60.6	〃
13	100	12	294.1	736.6	77.1	58.0	〃
14	100	11	175.6	746.1	77.2	42.3	比較鋼
15	100	12	183.4	744.5	77.6	55.4	〃
16	100	12	186.1	739.3	77.3	66.8	〃
17	100	16	197.0	741.4	79.2	74.5	〃
18	100	18	160.5	744.4	79.6	95.1	〃
19	100	33	192.7	749.5	86.3	90.8	〃
20	100	9	209.7	752.3	75.9	69.8	〃
21	100	8	201.1	761.9	75.6	71.0	〃
22	100	6	268.2	771.3	74.7	67.6	〃
23	100	3	216.3	808.7	73.2	77.8	〃
24	100	3	248.5	802.4	73.2	74.2	〃
25	100	5	361.8	787.8	73.8	61.6	〃
26	100	11	289.8	741.2	76.9	62.0	〃
27	41	11	193.3	869.3	70.7	31.9	〃
28	33	26	213.6	892.8	76.5	17.5	〃
29	41	17	195.8	864.4	72.8	36.1	〃
30	46	17	193.0	852.4	73.8	38.1	〃
31	43	19	198.4	861.4	74.1	34.4	〃
32	—	—	204.7	—	—	19.0	〃
33	—	—	193.5	—	—	25.0	〃

[0035] Front Naka and No.1-13 are the 1st - the 4th invention steel. moreover -- No.14-26 are the steel which raised No.1-13 to Si out of range [this invention]. Further No.26-31 are the steel with which components other than Si deviated from the proper range of this invention. in addition -- No. -- 32 and 33 are the free cutting steels which added Pb to JIS S25C and JIS S45C Although each No.1-26 excels Pb free cutting steel in machinability, it reaches No.1-13, so that clearly from Table 3. Deformation resistances are all if No.14-26 are compared. No.14-26 are higher and it is inferior to formability in cold forging compared with No.1-13 which are invention steel. moreover -- It is low, therefore a deformation resistance is remarkable, and No.27-31 have a high rate of graphitization. Although machinability is superior to Pb free cutting steel, it is less than this invention steel.

[0036] Example 2 table 4, Steel (improvement element addition steel in machinability) of a chemical composition shown in Table 5 was used as 52mmphi steel bar like the example 1. Rate of graphitization of the obtained steel materials, Graphite particle size, The investigated result is collectively shown in Table 6 about hardness and a tool life. Sample offering steel No.1-13 are the example of the 5th invention steel. Moreover, No.14-26 remove improvement elements in machinability, such as Pb which is an indispensable component, Bi, and Te, calcium, from invention steel. No.27-28 have an indispensable alloying element for graphitization out of range in this invention. Furthermore, it reaches No.29 and 30 is JIS. It is Pb free cutting steel which added Pb, Bi, and Te to the carbon steel for machine structures. If not only a tool life is high, but comparison steel No.14-26 are compared with this invention steel and the direction of this invention steel compares it with steel conventionally, the tool life will improve extremely. Furthermore, although it is lower order on the whole compared with comparison steel No.14-26, the rates of graphitization of this invention steel are because [, such as this and 700 degree-Cx10h,] a short time was processed comparatively, and if the processing time is extended to about 30h as mentioned above, they can aim at much more improvement in a life. Since comparison steel No.27 and 28 have the low rate of graphitization, a tool life is very low and inferior to machinability.

[0037]

[Table 4]

[0038]
[Table 5]

No.	化学組成 (mass%)																					区分
	C	Si	Mn	Al	B	N	O	Ni	Cu	Co	Cr	Mo	V	Nb	Ti	P	S	Pb	Bi	Te	Ca	Se	
1	0.14	0.39	1.79	0.015	0.0038	0.0042	0.0007	0.51	–	–	–	–	–	–	0.005	0.006	0.008	0.08	0.09	–	–	–	第5発明鋼
2	0.37	0.47	1.21	0.019	0.0042	0.0083	0.0015	–	0.36	–	–	–	–	–	–	0.015	0.015	–	0.19	0.04	–	–	
3	0.53	0.24	0.44	0.018	0.0039	0.0075	0.0018	0.53	–	–	–	–	–	–	–	0.007	0.023	–	0.09	–	–	0.042	
4	0.75	0.38	0.44	0.006	0.0038	0.0136	0.0024	0.39	0.37	–	–	–	–	–	–	0.019	0.205	–	0.18	0.42	–	0.012	
5	1.03	0.45	0.36	0.012	0.0128	0.0098	0.0029	–	–	0.73	–	–	–	–	0.040	0.017	0.214	0.16	0.28	0.18	–	0.041	
6	1.33	0.09	0.75	0.017	0.0031	0.0021	0.0013	0.44	–	0.43	–	–	–	–	–	0.016	0.018	0.08	0.09	–	–	–	
7	0.54	0.21	0.42	0.015	0.0034	0.0082	0.0012	1.58	–	–	0.26	–	–	–	–	0.019	0.055	–	0.18	–	–	0.087	
8	0.53	0.18	0.45	0.014	0.0038	0.0085	0.0014	1.01	–	–	–	0.33	–	–	–	0.045	0.015	0.24	0.31	–	0.018	0.025	
9	0.53	0.19	0.45	0.019	0.0036	0.0083	0.0016	1.28	–	–	–	–	0.21	–	0.025	0.026	0.018	0.09	–	0.32	0.125	0.084	
10	0.54	0.21	0.45	0.018	0.0025	0.0085	0.0019	1.12	0.53	0.81	–	–	–	0.23	0.023	0.019	0.022	0.15	0.24	0.22	0.017	0.042	
11	0.53	0.48	0.33	0.015	0.0033	0.0083	0.0018	1.11	–	–	0.36	–	–	0.22	0.022	0.067	0.098	–	–	0.38	–	0.087	
12	0.53	0.49	0.41	0.016	0.0032	0.0082	0.0019	1.40	0.53	–	–	0.32	0.19	0.19	0.023	0.072	0.145	–	0.18	0.42	–	0.012	
13	0.54	0.55	0.41	0.019	0.0046	0.0081	0.0016	0.91	–	0.33	0.20	0.22	0.18	–	–	0.006	0.002	0.07	–	–	–	–	

[0039]
[Table 6]

No	化学組成 (mass%)																					区分
	C	Si	Mn	Al	B	N	O	Ni	Cu	Co	Cr	Mo	V	Nb	Ti	P	S	Pb	Bi	Te	Ca	Se	
14	0.14	0.39	1.79	0.014	0.0038	0.0042	0.0006	0.51	–	–	–	–	–	–	0.005	–	–	–	–	–	–	–	比較鋼
15	0.37	0.47	1.21	0.018	0.0042	0.0083	0.0015	–	0.36	–	–	–	–	–	–	–	–	–	–	–	–	–	
16	0.53	0.24	0.44	0.007	0.0039	0.0075	0.0023	0.53	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
17	0.75	0.38	0.44	0.018	0.0038	0.0136	0.0025	0.39	0.37	–	–	–	–	–	–	–	–	–	–	–	–	–	
18	1.03	0.45	0.36	0.016	0.0128	0.0098	0.0017	–	–	0.73	–	–	–	–	0.040	–	–	–	–	–	–	–	
19	1.33	0.09	0.75	0.017	0.0031	0.0021	0.0018	0.44	–	0.43	–	–	–	–	–	–	–	–	–	–	–	–	
20	0.54	0.21	0.42	0.016	0.0034	0.0082	0.0022	1.58	–	–	0.26	–	–	–	–	–	–	–	–	–	–	–	
21	0.53	0.18	0.45	0.018	0.0038	0.0085	0.0014	1.01	–	–	–	0.33	–	–	–	–	–	–	–	–	–	–	
22	0.53	0.19	0.45	0.016	0.0036	0.0083	0.0015	1.28	–	–	–	–	0.21	–	0.025	–	–	–	–	–	–	–	
23	0.54	0.21	0.45	0.019	0.0025	0.0085	0.0012	1.12	0.53	0.81	–	–	–	–	0.023	–	–	–	–	–	–	–	
24	0.53	0.48	0.33	0.018	0.0033	0.0083	0.0022	1.11	–	–	0.36	–	–	–	0.022	–	–	–	–	–	–	–	
25	0.53	0.49	0.41	0.017	0.0032	0.0082	0.0015	1.40	0.53	–	–	0.32	0.19	–	0.023	–	–	–	–	–	–	–	
26	0.54	0.28	0.41	0.016	0.0046	0.0081	0.0021	0.91	–	0.33	0.20	0.22	0.18	–	–	–	–	–	–	–	–	–	
27	0.53	0.18	0.83	0.018	0.0036	0.0104	0.0025	–	–	–	–	–	–	–	–	0.001	0.004	–	–	–	–	–	
28	0.51	0.29	0.78	0.019	0.0002	0.0075	0.0021	0.42	–	–	–	–	–	–	–	0.001	0.004	–	–	–	–	–	
29	0.53	0.22	0.86	0.025	0.0001	0.0073	0.0015	–	–	–	–	–	–	–	–	0.012	0.016	0.35	–	–	–	–	
30	0.25	0.24	0.58	0.026	0.0001	0.0081	0.0017	–	–	–	–	–	–	–	–	0.011	0.015	0.36	–	–	–	–	

供試材 No.	黒鉛化率 (%)	黒鉛粒径 (μm)	硬さ (Hv)	変形抵抗 (MPa)	限界圧縮率 (%)	工具寿命 (min)	備　考
1	65	13	186.4	818.3	72.3	43.9	第5発明
2	53	14	193.8	845.9	71.2	53.5	〃
3	63	16	158.9	822.9	71.0	55.1	〃
4	52	22	141.7	848.2	74.8	63.2	〃
5	100	33	190.4	737.8	74.9	109.3	〃
6	61	15	205.2	827.5	79.6	90.2	〃
7	82	13	202.9	779.2	72.5	70.7	〃
8	52	14	197.0	848.2	72.6	76.0	〃
9	72	10	236.4	802.2	73.1	64.4	〃
10	100	11	186.3	737.8	71.2	100.1	〃
11	61	10	199.2	827.5	69.4	62.0	〃
12	77	10	292.3	790.7	68.4	72.5	〃
13	97	14	181.4	744.7	69.2	66.8	〃
14	68	13	184.6	811.4	72.3	34.6	比較鋼
15	58	14	193.8	834.4	71.2	40.5	〃
16	63	16	158.9	822.9	71.1	48.8	〃
17	54	22	141.7	843.6	73.9	46.9	〃
18	100	33	190.4	737.8	73.5	83.6	〃
19	68	15	205.2	811.4	75.0	86.9	〃
20	88	13	202.9	765.4	78.3	60.1	〃
21	76	14	197.0	793.0	71.2	53.4	〃
22	85	10	236.4	772.3	71.3	60.1	〃
23	100	11	186.3	737.8	72.0	74.5	〃
24	80	10	199.2	783.8	69.9	60.5	〃
25	100	10	292.3	737.8	68.9	60.8	〃
26	89	14	181.4	763.1	72.3	61.1	〃
27	45	41	206.0	864.3	73.8	41.8	〃
28	48	46	204.3	857.4	73.9	42.3	〃
29	—	—	193.7	—	—	19.0	〃
30	—	—	193.7	—	—	25.0	〃

[Translation done.]